RESTORATION ECOLOGY
The Journal of the Society for Ecological Restoration

REVIEW ARTICLE

Ecological restoration hierarchy as a lens to reveal the foundational economic and legal structures impeding restoration

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Abstract

Introduction: Biodiversity loss is accelerating due to habitat destruction, economic expansion, and insufficient conservation efforts. Traditional mitigation strategies, which focus on minimizing harm rather than reversing damage, are inadequate for achieving net biodiversity gain.

Objectives: This article introduces the restoration hierarchy, a framework prioritizing full ecosystem restoration over partial restoration and mitigation to implement ambitious restoration efforts along the widely used restoration continuum.

Methods: The methodology comprises a case study approach combined with a literature review on ecological restoration, economic cost–benefit analysis, and legal analysis into the foundational legal structures impeding restoration.

Results: Using Finnish dam removals as a case study, we demonstrate that large-scale, full restoration yields not only the greatest ecological benefits, but also the greatest social welfare in a cost–benefit analysis. Despite ecology and economics aligning on restoration, legal structures currently obstruct large-scale restoration by prioritizing short-term private economic interests, protecting existing land-use rights, and limiting ambitious restoration efforts. We identify six key structural biases in law altogether, for instance, property rights, the relative permanence of resource permits, and the limited scope of application of restoration laws.

Conclusions: The article concludes that both ecological and economic perspectives support the consideration of full restoration at sufficient scale, rather than implementing fragmented restoration measures. Current legal structures in place, however, slow down or impede such ambitious approaches to restoration.

Implications for Practice: By aligning cost–benefit analyses with broader ecological scales, policymakers can facilitate the adoption of the restoration hierarchy and provide a meaningful contribution to biodiversity recovery. The restoration hierarchy provides a structured approach to rethinking restoration priorities, ensuring that ecological considerations take precedence when long-term social welfare justifies it. In line with this, practitioners should prioritize interventions, such as dam removals, that deliver the greatest ecological and social benefits. However, legal frameworks often impede these efforts by protecting short-term private interests and entrenched land-use rights. Addressing these structural barriers through legal reform is essential for enabling practitioners to implement restoration at meaningful ecological scales.

Key words: biodiversity, cost–benefit analysis, ecology, law, restoration hierarchy

Introduction

Fragmentation, degradation, and loss of habitats contribute to biodiversity loss at an alarming rate, bearing increasing risks to people and economies (IPBES 2019; Dasgupta 2021; Cowie et al. 2022). The increase in global economic activity and the ensuing demand for space and natural resources have driven the negative development since the 1950s (IPBES 2019). From an ecological perspective, conserving pristine habitats and mitigating negative human impacts on near-natural habitats are primary means to promote biodiversity (Benayas et al. 2009). Sluggishness in establishing sufficient spatial protection measures has, however, incurred an ecological debt to the planet

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Author contributions: NS, S-TP led the writing of the manuscript. NS, S-TP, AI authored the Introduction; KT, SK, NS, and AI, JA, and NS, S-TP authored specific sections of the manuscript; all commented and edited the manuscript before submission.

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doi: 10.1111/rec.70216
Supporting information at:
http://onlinelibrary.wiley.com/doi/10.1111/rec.70216/suppinfo

(IPBES 2019; Dasgupta 2021; European Commission 2021). Subsequently, conservation and mitigation efforts alone no longer suffice to tackle biodiversity loss *because they do not lead to a net increase in biodiversity* (Richardson 2016; IPBES 2019; CBD 2022). The same applies to previous policies, legal instruments, and conceptual tools; they no longer suffice to manage and govern biodiversity loss in its current form (Foster & Bell-James 2024). A prime example is the *mitigation hierarchy*, the key conceptual and policy framework for avoiding, mitigating, remediating, and offsetting biodiversity harm from *new* human activities (Arlidge et al. 2018). While important, the mitigation hierarchy falls short of providing tools for a net gain in biodiversity, hence prompting the need for ecological restoration on a landscape scale and affecting various economic sectors (Gann et al. 2019, 22).

Systemic restoration alongside the current magnitude and scale of economic activities and land use is challenging when restoration requires ceasing existing economic activities. For instance, hydropower rivers have gone through impoundments replacing riffles. While connectivity could be improved with mitigation measures like fish bypasses, reinstating the rapids is impossible if the dam's impoundment persists (He et al. 2024; Stoffers et al. 2024). Coexistence can thus lead to a suboptimal result, with poor ecological outcomes and high economic costs.

The restoration agenda has been pushed by many governmental and nongovernmental initiatives (Correa Ayram et al. 2016). The UN Kunming-Montreal Global Biodiversity Framework seeks to restore 30% of degraded terrestrial and aquatic habitats by 2030 (CBD 2022). The European Union's recent Nature Restoration Law (NRL, 2024/1991) establishes legal obligations on Member States to improve and reintroduce terrestrial and aquatic habitats. These policies and laws do not sufficiently address the prioritization and balancing between economics and biodiversity. For instance, the NRL steers restoration activities mostly to existing nature conservation areas and sites where economic activities have already become obsolete (e.g., Art 9 (2); Stoffers et al. 2024), avoiding the comparison of existing economic activities against restoration values.

The failure to question existing socio-economic uses based on ecological needs does not concern only new restoration instruments. Existing instruments have narrowed down the legal scope of restoration obligations to, for example, the remediation of an industrial site at the sunset phase of the operation (Richardson 2016; Telesetsky et al. 2017; Cliquet et al. 2022). Some legal instruments, such as the EU Water Framework Directive (WFD, 2000/60/EC), have established broad restoration obligations across water bodies but faced significant legal obstacles in implementation, such as property rights (Puharinen 2024). From an economic point of view, the case-by-case cost–benefit analysis—toward which the current legal systems steer—disfavors calculating restoration efforts for people and nature overall. Accordingly, full implementation of ambitious restoration policies is unlikely without major changes to existing institutional structures (Meadows 1999; Pascual et al. 2023).

To move past these challenges, the restorative continuum developed by the Society of Ecological Restoration (SER) provides fruitful starting points for structuring and prioritizing restoration measures (Gann et al. 2019, p 22). Yet, we argue, first, that the conceptualization of restoration efforts should press for an even more explicit normative shift from mitigation hierarchy to a *restoration hierarchy*. Such a hierarchy conceptualizes systemic restoration efforts that target broader ecological scales and question existing socio-economic activities. The restoration hierarchy's primary objective is the full restoration of ecosystems as self-sustaining entities.

Second, we argue that the restoration hierarchy offers a lens to uncover the negative legal and economic evaluation structures for implementing ambitious ecological restoration goals. We show that the current legal frameworks are geared toward mitigating the environmental damage from new and ongoing human activities—or restoring ecosystems in narrowly defined contexts—rather than questioning the viability of these activities altogether to cater for full ecological restoration at scale. Similarly, economic trade-off narratives and measures around restoration actions are biased toward the present-day context, focusing on maintaining existing economic activities over long-term welfare–economic potential. With targeted policy changes, these institutional structures could be changed to support the restoration policies and their implementation.

The article builds on the ecological observation that restoration needs to be put into an appropriate spatial and systemic context. Arguing our analysis to be applicable in the implementation of the ecological restoration agenda at large, we use Finnish constructed rivers as an example to illustrate the governance implications of the restoration hierarchy, where biodiversity loss is particularly pronounced (Iho et al. 2023).

The article is structured so that the next section shows how and why there is a need to emphasize the importance of full ecological restoration at scale. In Economic Evaluation Frameworks for Nature Restoration section, we provide a cost–benefit analysis example of restoration hierarchy implementation in a river restoration context. The example reveals the pitfalls of the current cost–benefit analysis models in a restoration context and charts a pathway for a more holistic analysis. The Law's Structural Biases Against Nature Restoration section showcases structural biases in legal systems in Finland and the EU—which are partly generalizable globally—that impede the implementation of the restoration hierarchy—and changes to which could ratchet transformative societal change toward meeting the ambitious restoration objectives. The last section concludes.

Ecological Foundations of the Restoration Hierarchy—Dammed Rivers as an Example

Restoration generally increases biodiversity and ecosystem service supply of degraded ecosystems, yet the levels typically fall behind the intact reference systems (Benayas et al. 2009). Despite this, restoration measures are vital for a net positive biodiversity impact. In some contexts, an ecosystem starts to heal itself as soon as the dominant human activity ceases (passive restoration). Others require active restoration measures modifying physical habitats, providing ecosystems and target species better possibilities to achieve natural-like status (Acuña et al. 2013; Chazdon et al. 2024).

One of the most known prioritization frameworks for restoration measures is the "restorative continuum" developed by the Society of Ecological Restoration (SER) (Gann et al. 2019, p 22). It includes a suite of measures ranging from the mitigation of negative societal and economic impacts on ecosystems to remediation of specific sites, for instance, by removing harmful substances and nutrients and in doing so, allowing nature to recover. Rehabilitation refers to efforts toward restoring the functionality and productivity of ecosystems. Full ecological restoration refers to ecosystems that are close to their native—or in line with climate change—best achievable status (Gann et al. 2019).

Whereas the SER restorative continuum can be read in line with first taking ecologically less ambitious measures that are societally more feasible, an urge to read the continuum in this light should be resisted. From an ecological perspective, as also pointed out by the developers of the SER restorative continuum (Gann et al. 2019), full restoration is almost without exception the best course of action, albeit that it may need to be complemented with the other measures along the continuum. Stressing this may seem an obvious point but one that is crucially important for the economic cost–benefit analysis as shown in Economic Evaluation Frameworks for Nature Restoration section and the subsequent legal considerations as shown in The Law's Structural Biases Against Nature Restoration section.

At the same time, the restoration continuum is often presented as a temporal continuum starting from first-hand restoration measures and ending up in full restoration, a presentation that does not explicitly emphasize the normative dimensions of prioritizing restoration measures based on their ecological impact. Our reading of the SER restorative continuum, which we call the restorative hierarchy, prioritizes, as a main rule, the full restoration potential of an ecosystem, which is then the ecological counterfactual for comparing alternative restoration actions. This is followed by a partial, nature-based restoration where some of the economic activities are forfeited, and the recovery is supported with active restoration. The third-best option is to remedy the site from pollutants or other ecological harm. This is based on the well-established understanding of ecosystem structure and function, namely that many species, populations, and ecosystem functions depend on extensive and well-connected habitats (Rudnick et al. 2012). Sufficient connectivity is vital for species metapopulations and the organization of biological communities as it allows dispersal and gene flow among habitat patches (Baguette et al. 2013). Restoration of qualitatively perfect, but poorly connected, habitat patches does not allow this. Dispersal of species and transfer of matter should be guaranteed through habitat corridors (such as free-flowing river systems, Kondolf et al. 2006) or fragments of habitats with sufficient quality and size (e.g., stepping-stone patches of forests; Saura et al. 2014).

Considering an example, freshwater ecosystems are the most vulnerable to biodiversity loss (Dudgeon 2019; Reid et al. 2019). Damming for hydropower and other purposes has altered the flow, habitats, and biota of rivers (Kuriqi et al. 2021). Dams break the ecological continuum by changing rivers into a chain of separate pools (Ellis & Jones 2013; Benejam et al. 2016). Hydropower also alters natural flow patterns to which the local biological communities have adapted over the course of millennia (Poff et al. 1997). Fragmentation hinders migration between the key habitats needed by migratory species to complete their life cycles, which has contributed to the collapse of valuable trout and salmon stocks (e.g., Gibeau et al. 2017). Free-flowing rivers, or functional semi-artificial structures like nature-like fishways, are essential migrating corridors for diadromous fish species (Verhelst et al. 2021).

In rivers where full restoration is not socio-economically, politically, or legally feasible, partial recovery can be achieved, for instance, by removing some critical dam(s) in lower reaches of the river, allowing fish to reach some of the original spawning grounds (Forget et al. 2018). Alternatively, environmental flow (Renöfält et al. 2010) and nature-like fishways can be appropriate restoration measures to help improve ecosystem functioning while hydropower generation continues (Sánchez-Pérez et al. 2022; Tolonen et al. 2024). Stream habitats supported by nature-like fishways also provide food and suitable habitat for a high diversity of species including rich macroinvertebrate fauna (Gustafsson et al. 2013). Migration of salmonid fish species may also benefit from technical fishways that minimize the use of water diverted from the turbines (Bunt et al. 2012). Ecologically, these are least effective as they poorly support the upstream migration of nonsalmonid fish species while disregarding downstream migration (Landsman et al. 2018). Finally, other measures—such as in-stream habitat and catchment restorations and fisheries management, can be considered alongside other measures on the restoration hierarchy (Fig. 1).

Implementing the restoration hierarchy raises two key questions: What is the appropriate scale of restoration efforts, and how would one justify a move from full restoration to the less ecologically optimal steps? The scale question should be based on an ecologically sound understanding of ecosystem function and connectivity, which favors geographically large, fully restored habitats over smaller half-measures. The appropriate geographical scale of restoration activities varies across ecosystem contexts. We argue that the move from one step to another should be justified based on established economic or other decision support tools, such as cost–benefit analysis (CBA). CBA can also lead to prioritizing full, large-scale restoration over other measures if the applicable legal and governance setting supports moving past case-by-case analysis.

Economic Evaluation Frameworks for Nature Restoration

Economics, Environmental Protection and Restoration

Economics classifies insufficient provision of public goods, like many ecosystem services, as market failures. Market participants typically consider only private costs and benefits, whereas from the societal point of view, the ensuing market price should reflect *social* costs and benefits (such as ecosystem services) (Baumol & Oates 1988).

Figure 1. River restoration hierarchy with related restoration and management measures.

Access to affordable and reliable energy is one of the 17 UN Sustainable Development Goals. Electricity security is thus a public good. It comprises two elements: capacity to match peak demand and ability to provide consistent electric current under varying supply and demand. Batteries and demand-side responses are projected to provide most of the short-term flexibility after 2035. Hydropower reservoirs and thermal power will remain key providers of seasonal flexibility (IEA 2024; Boes et al. 2023). Run-of-river facilities without upstream reservoirs do not contribute to flexibility but retain their detrimental biodiversity impacts. Hence, they represent sites most likely optimal for full restoration.

Cost–Benefit Analysis as a Key Evaluation Method

Cost–benefit analysis (CBA) compares discrete management alternatives whose potentially uncertain costs and benefits incur between present moment and the future (Bateman et al. 2013). An environmental CBA considers the effects on both private profits and societal benefits, which may require monetization of nonmarket goods like ecosystem services (Bergstrom & Loomis 2017). The welfare outcomes are typically expressed as Net Present Value (NPV), the sum of discounted long-run costs and benefits.

In a hydropower context, the set of alternative restoration choices could be constructing (1) a technical fish-bypass, (2) a nature-like bypass, or (3) decommissioning the facility and restoring the river. In a CBA, quantifiable relevant decision-making factors and boundaries are identified and categorized, and their uncertainties assessed. In the United States, the Federal Energy Regulatory Commission (FERC) uses CBAs to assess the social benefit of relicensing hydropower operations (Levine et al. 2021). The evaluation requires at least qualitative consideration of environmental and cultural factors. If the license is renewed, it may prompt building or improving fish passages. FERC has relicensed 501 operations between 1990 and 2010 (Rudberg et al. 2015), while over 450 operations were decommissioned in the period from 1968 to 2019 (Habel et al. 2020).

The results of environmental CBA depend on a set of discrete choices it scrutinizes. *If full restoration is not considered an option, it cannot emerge as an optimal outcome*. Further, using CBA as an economic prioritization tool to maximize social welfare assumes all relevant values are captured in commensurate money measures. The value context under which a CBA is conducted should thus be clear to the policy maker. If pluricentric or biocentric values are likely to constitute a large share of values, they should be assessed parallel to CBA (see Pascual et al. 2023).

Cost–Benefit Analysis in a Concrete River Restoration Case

Moving from the SER restorative continuum to our proposed restoration hierarchy may substantially change the often-dichotomous recommendations of CBA for interconnected ecosystems. In some sense, the logic is trivial: if ecological benefits are interconnected, the sum of benefits of isolated analyses will be different from the benefits of an analysis considering the entire ecosystem continuum. We argue for a stepwise approach. First, for a given location, the CBA should assume other interconnected locations as fully restored. If this results in full restoration as the recommended option, then a comprehensive CBA encompassing all interrelated activities and locations should be conducted.

Let us illustrate the stepwise approach with a simplified analysis, where we use a one-dimensional proxy to capture all market and nonmarket benefits from ecological improvements. We follow a real-world case in River Hiitola, South-East Finland, where all three hydropower facilities were purchased from two different companies, and decommissioned by a local NGO in 2021, 2022, and 2023. The trade was boosted by the decision (18/0021/2) of the Vaasa Administrative Court prompting the facilities to construct (costly) fish-passages.

Prior to the damming, the threatened land-locked salmon (Salmo *salar* m. Sebago) migrated from its feeding grounds in Lake Ladoga (Russia) to Hiitola to spawn. After the dam removals and stream restorations, the newly established spawning grounds have proven highly productive in terms of spawning fish (Supplement S1). This exemplifies nature's ability to bounce back if the measures are done on ecologically meaningful scales.

We assume to be at a point in time before the trades. However, we utilize ex-post measurements of ecological impacts, and realized decommissioning and restoration costs as well as purchase prices of the facilities. For each facility, we consider two alternatives: either to build functioning fish passages according to the court ruling and continue electricity generation, or to decommission the facilities and restore the rapids.

Table 1 presents the fundamental information on the three facilities and the rapids restored.

Table 1. Key characteristics of the Hiitola restorations. Purchase prices are obtained by dividing the total cost of purchases by the electricity generation capacity of the facilities. Decommissioning and restoration costs are actual, rapid specific costs. Acreage of restored rapids, personal communication, Markus Tapaninen, Center for Economic Development, Transport and Environment, South-East Finland.

	Purchase Price	*Decommissioning and Restoration Cost*	*Acreage of Restored Rapids*
Kangaskoski	490,300 €	592,000 €	0.62 ha
Lahnasenkoski	684,100 €	1,301,100 €	0.58 ha
Ritakoski	310,100 €	889,300 €	0.31 ha

The total cost of purchasing the facilities was 1,484,500 €. As the individual sales prices were not disclosed, we assume the price of each facility to be proportional to the annual quantity of electricity generated: 3.23 GWh for Kangaskoski, 4.50 GWh for Lahnasenkoski, and 2.04 GWh for Ritakoski. The actual sales prices were at least as high as the opportunity costs of the owners. These are determined by the net present value of the net revenues in perpetuity, *including the investment and operational costs of fish passages*. That is, all values of electricity generation in the tables below include the costs of fish passages. Due to the court ruling, the operators did not have the option of continuing without fish passages. For decommissioning and restoration costs, we use realized, facility-specific values.

We assume that ecologically, the restored rapids will follow the succession path for trout and salmon of the first restored rapid, Kangaskoski. During its third year, it produced 1,920 salmon younglings (1+). The densities and estimated total numbers of salmon and trout in Kangaskoski after decommissioning are given in Supplement S1.

There are some spawning grounds for trout in smaller headwaters upstream of the third facility. We assume their total area to be about 0.6 ha and that their productivity is similar for trout as the first year of Kangaskoski. We assume no salmon is reproduced there.

River restoration generates many amenities (Brouwer & Sheremet 2017). Here, we use the salmon and trout younglings reproduced in the newly restored habitats as the only source of nonmarket benefits. As a proxy for this value, we use the fixed penalty for an illegally fished adult landlocked salmon, 7,510 €, and for lake trout, 2,440 € (Regulation of the Ministry of Agriculture and Forestry on the Value of Endangered and Declining Fish Species, 614/2019, Art 1(4) and (11)). These values reflect the *actual replacement cost* of an adult fish, considering the costs of breeding and survival rates until adulthood. To avoid double counting, we only consider the value of 1+ younglings. Based on expert evaluations, we assume that 50% of these will eventually become smolts, of which 1% survive to adulthood. Therefore, the value of one 1-year salmon youngling becomes 38 € and trout 12 €. The value stream is discounted using a social discount rate of 2%.

Our illustrative CBA omits certain benefits and costs considered in the Nordic hydropower CBA literature. We do not consider the electricity market effects (see, e.g., Vehviläinen 2023 for Nordic context) from the decommissioning of the three hydropower stations (see, e.g., Johansson & Kriström 2011) as they did not partake in grid regulation and constituted only 0.6 per mille of the national (single market area) hydropower capacity. For the same reason, we also omit the substitution costs in additional CO_2 emissions (Johansson & Kriström 2011). All investment costs and their timing are implicitly included in the sales prices as they affect the reservation price the owners had by the time of trade negotiations. We also omit potential recreation (see, e.g., Håkansson 2009; Ek et al. 2024) and property value changes (see, e.g., Loomis 2006; Lewis et al. 2008; Provencher et al. 2008). The decommissioning is expected to increase the recreation values, but there are no quantitative estimates of potential use-values. Restricted commercial fishing is starting this year. Hence, there is no data yet on the direct and indirect economic value it will generate locally. We note that nonuse values are the prevalent source of benefits in river restoration (see Loomis 2006; Håkansson 2009; Artell et al. 2022), and our use of a protection cost-based proxy of endangered fish values represents a lower bound for market and nonmarket benefits. The inclusion of these benefits would strengthen the qualitative outcomes of our analysis.

Table 2 presents the components of the CBA-results for the most productive facility with the highest decommissioning costs, Lahnasenkoski. There are thus two options: invest in fish passages and continue electricity generation (*Continue*) or decommission the facility (*Decommission*). Together with similar options for the two other facilities, this generates eight combinations. For the purposes of our illustration, it suffices to present the outcomes of the following three: 1. Lahnasenkoski: *Continue*; other facilities: *Continue*, 2. Lahnasenkoski: *Decommission*; other facilities: *Continue*, and 3. Lahnasenkoski: *Decommission*; other facilities: *Decommission*. We use the marginal changes as the values for ecological benefits. For instance, the benefits in the third combination are the added value of *All Decommission* compared to the *Continue*, *Decommission*, *Decommission*.

Table 2 exemplifies the effects of restoration hierarchy. If only alternatives 1 and 2 were considered, it would be socially optimal to build the fish passage and continue operations. However, if we assume the rest of the river is free, decommissioning the Lahnasenkoski provides by far the highest net benefits.

According to our proposed approach, the results of the above analysis prompt us to conduct a comprehensive analysis, considering the costs and benefits of all 12 combinations. We only present three of these: All: Continue (1), Kangaskoski and Lahnasenkoski: Decommission, Ritakoski: Continue (2), and All: Decommission (3) (Table 3).

We observe that the welfare maximizing option is to decommission all the facilities and restore the rapids in their entirety. The option with the second highest benefits is to decommission the two facilities in the river while continuing electricity generation at Ritakoski. In this case, most of the potential spawning grounds by the two lowest rapids would be restored. Furthermore, the decommissioning of Ritakoski is relatively costly compared to the size of the obtainable spawning area. Our analysis omits the fact that having the uppermost facility in operation would disturb the flow regime and thus impede the survival of salmonoid younglings in the two restored downstream rapids. Taking this into account would lower the net benefits of this choice. The outcomes are sensitive to the choice of the social discount rate. For values above 2.25%, it would be most profitable to have all facilities continue their operations. We stress that our analysis did not consider any other nonmarket benefits than salmonid-related values, representing a lower bound benefit. Our purpose was to showcase the implications from following the proposed restoration hierarchy, that is, explicitly considering also the alternative of decommissioning all facilities. The practice would guarantee that we shall not omit the welfare maximizing alternative from cost–benefit analysis.

Our example stresses the importance of legal frameworks in place to promote and allow full restoration at ecologically meaningful scales (e.g., across an entire river continuum). We turn next to those legal systemic properties that typically hold back or even prevent the consideration of ecological continuums. Changes to the legal properties would likely strongly support the increased adoption of the higher levels of the ecological restoration hierarchy in line with the net positive biodiversity targets.

The Law's Structural Biases Against Nature Restoration

Starting Points

Operationalizing the normative component of the restoration hierarchy—explicit prioritization of restoration measures and implementation on a landscape scale—requires the steering force of the law. Notably, prominent legal instruments for systematic nature restoration have been adopted across jurisdictions

Table 2. Costs and benefits from the viewpoint of an individual facility, Lahnasenkoski. It can be either decommissioned (D) or it can continue its operations (C). Other facilities face the same choice, yielding eight combinations: DDD, DDC, DCD, DCC, CDD, CDC, CCD, CCC. The table presents the economic outcomes for Lahnasenkoski for three of these: CCC, DCC, and DDD.

Alternative	*1*	*2*	*3*
Lahnasenkoski	Continue	Decommission	Decommission
Other facilities	Continue	Continue	Decommission
Costs (NPV)			
Decommissioning and restoration	0 €	−1,301,100 €	−1,301,100 €
Benefits (NPV)			
Electricity generation	684,100 €	0 €	0 €
Value of salmonoid production	900 €	44,986 €	2,718,053 €
Total net benefits (NPV)	685,000 €	−1,256,114 €	1,416,953 €
Choice of alternative	No	No	Yes

Table 3. Total costs and benefits for three combinations of facilities' continuation or decommissioning choices. The highest total net benefit is obtained from decommissioning all three facilities.

Alternative	*1*	*2*	*3*
Kangaskoski	Continue	Decommission	Decommission
Lahnasenkoski	Continue	Decommission	Decommission
Ritakoski	Continue	Continue	Decommission
Costs (NPV)			
Decommissioning	0 €	−1,893,100 €	−2,782,500 €
Benefits (NPV)			
Electricity generation	1,484,525 €	310,100 €	0 €
Value of salmonoid production	900 €	3,499,090 €	4,818,003 €
Total net benefits (NPV)	1,485,425 €	1,916,090 €	2,035,503 €
Choice of alternative	No	No	Yes

in recent years. At the international level, the UN Kunming-Montreal Global Biodiversity Framework mandates state parties to restore 30% of degraded terrestrial and aquatic habitats by 2030. In the EU, the Water Framework Directive requires EU member states to implement all necessary measures—including river restoration measures—to achieve good status of all waters (Art 4(1)), unless socio-economic reasons justify derogating from this primary objective (Art 4(4)–(7)). The EU Nature Restoration Law further requires member states to adopt measures to restore the quality of terrestrial and aquatic habitats and reintroduce them to areas where they have been lost (Art 4(1) and (5), 5(1) and (2)) and, specifically, restore 25,000 km of free-flowing rivers by 2030 (Art 9(1)). These instruments can steer toward the realization of restoration efforts and the restoration hierarchy can provide a key conceptual tool for implementing these obligations.

Despite this, international, European, and national laws striving to improve environmental quality and restore nature frequently suffer from implementation challenges that are driven by legal systemic counterforces (Puharinen 2024). In this section, we explore how the legal regimes operating across legal cultures are shaped by "mitigation thinking," hence failing to accommodate ambitious ecological restoration. Law steers toward assessing the feasibility of restoration in the context of individuals' activities, where the economic interests of the operator are strongly protected. Hence, legal systems at large fail to support the restoration hierarchy. More specifically, we argue that there are six structural biases impeding systematic restoration along the restoration hierarchy:

1. Property rights grant a priority right to keep using natural resources and shield against legislative, executive, or judicial intervention.
2. Once granted natural resource use authorizations enjoy constitutionally protected permanence.
3. Law merely requires mitigation of biodiversity harm caused by new and existing economic activities without questioning the pursuit of the activity based on ecological prerequisites.
4. Business actors are to consider only the private economic benefit of natural resource use, and to oppose restoration.
5. Law explicitly requires restoration only in limited circumstances.
6. Law contains strong measures, like expropriation, for driving public interests, but these measures are more readily applicable to economic development than restoration.

We use the EU and Finnish legal systems to illustrate the structural biases of law, but similar biases can be found in legal systems across the globe (Richardson 2016; Cliquet et al. 2022; Foster & Bell-James 2024).

Property Rights Grant a Priority Right to Keep Using Natural Resources and Shield Against Legislative, Executive, or Judicial Intervention

Assignment and enforcement of property rights, where the owner has an a priori right to use the resource and exclude the use of others, is essential for allocation of resources among private parties (Starrett 2003). Treating resources as commons, where there are no rules of priority and individuals have equal access, leads to unsustainable exploitation (Hardin 1968). Consequently, legal systems often subject natural resources like land, forests, minerals, and waters to some variations of property rights or corresponding entitlements, granting the owner exclusive rights to use and regulate the property, if it does not interfere with the rights of others (Martin 2003; Starrett 2003). This alone, however, cannot justify any use of the property, as uses entailing harm to other property owners or public interests like environmental protection are often conditioned on acquiring a permit. Yet, as we show below, permitting regimes display their own biases driving biodiversity loss and impeding restoration.

Property rights significantly impede systematic nature restoration (Pascual et al. 2023). Legal systems recognize the right to property as a fundamental right, which entails constitutional limitations on public powers to promote restoration when it would restrict these rights (e.g., Article 1 of the Protocol to the European Convention for the Protection of Human Rights and Fundamental Freedoms; Article 17 of the Charter for Fundamental Rights of the European Union). This protection is not absolute, since the use of property may be regulated "by law in so far as is necessary for the general interest," like environmental protection. However, outright limitations to property rights require a proportionality assessment and must "respect the essence of these freedoms" (Charter Art 52(1)). Depriving the possibility to freely use the property altogether—such as full restoration—is conditioned on a fair compensation being provided to the owner and even then, the proportionality assessment might block the adoption of such a measure (Charter Art 17(1)). Thus, the freedom to use property is the primary rule, whereas the general interest limitations are an exception that need to be specifically legislated, carefully justified, and fully compensated. Consequently, nature restoration instruments tend to avoid imposing limitations that would interfere with the core of property rights; for instance, the NRL steers restoration to areas where there are least conflicts with property rights. Moreover, property rights shield every owner equally and individually, meaning that any restoration measures limiting these rights must be based on a case-by-case assessment, where the owners' economic interests and right to continue the activity are protected. Property rights therefore present a major hindrance to conducting CBA's at ecologically meaningful scales and the application of the restoration hierarchy.

Once Granted Natural Resource Use Authorizations Typically Enjoy a Constitutionally Protected Level of Permanence

Legal certainty is one of the cornerstones of developed legal systems (Fuller 1969; Radbruch 1990; Waldron 2008) and typically operates in conjunction with property rights. In essence, legal certainty means that legal rights and obligations are accessible and *predictable* "so that those affected by the law can reasonably anticipate the consequences of their actions" (Popelier 2008). This generic idea has gained numerous conceptual formats depending on the legal context. In a judicial sense, this translates to the *requirement of finality*, meaning that once resolved legal issues cannot be taken up by the court again (Harnon 1966). In the context of environmental permits, the idea of finality has been discussed as protection of legitimate expectations, meaning that those subject to administrative decision-making have a right to rely on established administrative decisions and that they do not change without a good reason and due notice (Forsyth 1988; Tridimas 1999; Schonberg 2000). In the legislative domain, it translates to a continuity requirement (Leisner 2002), meaning that legislatures should not make frequent changes to the law (Fuller 1969). All these forms of legal certainty, and the predictability that they invoke, are prominent in the context of property rights and market systems more generally as uncertainty of laws is poison to functioning markets (Ostojski 2020).

Contemporary international and domestic legal systems adopt only a narrow temporal understanding of restoration toward mitigating future biodiversity loss and not sufficiently revisiting the requirement of legal certainty (Richardson 2016; Telesetsky et al. 2017; Foster and Bell-James 2024). This concerns particularly the possibility to revise and even revoke past permit decisions (European University Institute 2014). In a hydropower context in Finland, permits enjoy a high level of permanence, both due to property rights to river flows and granted to permits (Hepola 2005; Belinskij & Soininen 2017). The 2011 Water Act and its predecessors have long maintained that once a hydropower operation is issued a permit to operate, the permit cannot be entirely revoked or considerably adjusted without the consent of the hydropower operator (Soininen et al. 2018; Iho et al. 2023). Some argue that the protection of legitimate expectations would prevent even the legislature from changing the legal status quo (Hepola 2005). While the latter argument can be questioned, the finality requirement of the law can entrench past hydropower decisions across the judicial, administrative, and legislative domains unless stronger measures, such as expropriation, are used to restore biodiversity.

Law Merely Requires Mitigation of Biodiversity Harm Without Conditioning the Pursuit of the Activity as Such Based on Ecological Prerequisites

This bias is founded in the *decoupling* paradigm rooted in neoclassical economic thought. In its simplest definition, it means decoupling the increase in economic output from corresponding negative impacts on the environment (OECD 2001). Here, environmental damages are viewed as externalities of economic activities to be reduced—without compromising the pursuit of the activities as such (Hickel 2019; Kotzé & Adelman 2023).

The mitigation hierarchy is a poster child of the decoupling paradigm. It seeks to mitigate the environmental impacts of economic activities, aiming at solutions that entail the least net environmental harm with minimal intrusion to economic interests at the project scale (Larsen et al. 2018; Cares et al. 2023). With such a mindset, ecological prerequisites or overall welfare aspects are not strongly factored into decision-making. The mitigation hierarchy forms the conceptual foundation for modern environmental law (Richardson 2016; Telesetsky et al. 2017; Foster & Bell-James 2024). For instance, permitting regimes typically do not question the pursuit of economic activities, and the scope of permit requirements aimed at mitigating environmental harms is shaped by economic feasibility (see, e.g., the EU Industrial Emissions Directive (2010/75/EU)). Such mitigation thinking is also reflected in the possibilities to address environmental harms of previously permitted activities (Reid 2008). For instance, the Finnish Water Act conditions permit amendments in a hydropower context to ensuring that the amendments do not significantly reduce the economic benefit gained from the project. Such a setting steers restoration to the fringes of private economic interests, fundamentally conflicting with the logic of the restoration hierarchy.

Business Actors Are Obliged to Consider Only the Private Economic Benefit of Natural Resource Use, and to Oppose Restoration

The core paradigm of neoclassical capitalism is that free markets and competition produce economic efficiency and welfare; hence, legal systems are built around protecting, facilitating, and steering toward active competition and private profit-seeking (Drexl et al. 2009). Corporate legislation often establishes the primary purpose of corporations as to maximize private profit-seeking (Sjåfjell & Mähönen 2024). Each business operator therefore seeks to maximize the volume of their operations by ascertaining property rights and environmental permits with favorable conditions. At the same time, safeguarding the public good is predominantly the responsibility of public administration. In the context of restoration measures—such as implementing environmental flows in existing hydropower plants—the operator must oppose any permit amendments that would decrease its private profits, while public administration faces the burden of justifying amendments. This setting is further complicated by information asymmetry, as the business operators have more specific and comprehensive information about their operations and environmental impacts but no incentives to disclose it to the authorities, as that could lead to limitations to profit-seeking.

In recent years, corporate due diligence laws have been developed in the EU and other jurisdictions seeking to steer corporations toward considering and working to limit the environmental damage of their operations. For instance, the EU Corporate Sustainable Due Diligence Directive (2024/1760/EU) requires corporations to implement a comprehensive due diligence system to assess, prevent, and mitigate the risks of adverse environmental impacts. It is quite clear, however, that the directive is not sufficient to resolve the full magnitude of this bias; for instance, since it does not question the corporate profit-maximization purpose (Sjåfjell & Mähönen 2024). Subsequently, the mismatch between corporate profit seeking and restoration for the public interest will continue.

Law Only Requires Restoration in Limited Circumstances

The extent of global-to-local biodiversity loss necessitates taking restorative action at landscape scales. However, legal frameworks at international, regional, and national levels alike are almost without exceptions based on the idea that ecological restoration is only required in limited circumstances. Richardson (2016) and Telesetsky et al. (2017) show how ecological restoration is typically reserved for the rehabilitation and remediation of specific sites after mining, industrial accidents, and the like. This is logical considering the biases presented above, especially property rights, permanence of permit decisions, and limitations of amending permit conditions. Here too, the environmental measures—restoration requirements—do not interfere with private economic interests but are situated at the fringes of the activity, to only apply once profit-seeking has ended or when restoration is an undesired and unexpected externality (e.g., industrial accident). Yet, this also means that the law's existing restoration obligations follow a fundamentally different logic compared to our restoration hierarchy and will thus not suffice to tackle biodiversity loss.

Law Contains Strong Measures, Like Expropriation, for Driving Public Interests, but These Measures Are more Readily Applicable to Economic Development Than Restoration

Legal systems in Europe and globally contain provisions empowering public authorities to expropriate private property in limited circumstances for the public interest (Sluysmans & Waring 2016). Typical legally justified circumstances include situations such as land acquisition for public services and utilities (Sluysmans & Waring 2016). Generally, public authorities may resort to expropriation as a last-ditch effort after voluntary measures (e.g., negotiations) have been exhausted, and the owner of the expropriated property will get fair or market value as compensation for the loss of property (Sluysmans & Waring 2016). This is a codification of the constitutional protection of property rights enshrining that no one may be deprived of his or her possessions, except in the public interest and in the cases and under the conditions provided for by law, subject to fair compensation being paid in good time for their loss (Charter Art 17).

Despite the state and public authorities having expropriation as a strong legal tool for land acquisition, it is rarely used to promote biodiversity protection and restoration at scale (Telesetsky 2017; Foster & Bell-James 2024). Quite the opposite, there are examples globally where public authorities use expropriation—either explicitly or de facto—in relocating nature to less economically valuable areas to boost economic development (Bradshaw 2019). This is a problem considering that a key challenge for restoration is the re-evaluation and downscaling of existing land use for economic activities, and in many contexts, there is at least one economic actor or property owner preventing the restoration at ecologically meaningful scales. This means that without expropriation, the legal space to consider restoration at meaningful geographical scales is highly limited.

Conclusions

The United Nations Kunming-Montreal Global Biodiversity Framework and the European Union's Nature Restoration Law emphasize restoration yet avoid challenging existing economic activities. By limiting restoration to economically inactive areas as per the mitigation hierarchy, these policies fail to establish clear priorities between ecological needs and socio-economic interests.

We propose complementing the mitigation hierarchy—which merely reduces negative biodiversity impacts and applies to new and ongoing projects—with a restoration hierarchy, a more proactive framework that prioritizes full ecosystem restoration at scale while requiring the phaseout of economic activities that incur cumulative social harm rather than the benefit. This framework is in line with the existing SER restorative continuum but explicitly prioritizes full restoration at scale over other, less ambitious restoration measures. At the core of this argument is the recognition that systemic restoration at the landscape level is essential for reversing biodiversity loss. This requires reducing or even ceasing ongoing economic activities in areas of full restoration. Partial restoration and harm minimization should only be considered if efforts to establish full restoration fail.

To illustrate the hierarchy in action, we study the restoration of rivers in Finland, where hydropower dams have significantly impacted biodiversity. While mitigation measures like fish bypasses can partially improve ecological conditions, full restoration—dam removal and habitat restoration—delivers far greater biodiversity benefits. The removal of three hydropower dams on Finland's Hiitolanjoki River demonstrated that full restoration leads to rapid ecological recovery, as seen in the resurgence of land-locked salmon populations. Allowing this viewpoint to move the boundaries of a case-by-case cost–benefit analysis reveals that when full restoration is considered within a systemic framework, it can emerge as both the most economically and ecologically viable solution.

Finally, we identify six structural biases in law that obstruct large-scale restoration:

(1) Property rights prioritize economic use, limiting restoration mandates.
(2) Natural resource permits are sticky, preventing or slowing down restoration efforts.
(3) Environmental law favors mitigation over restoration, reinforcing the status quo.
(4) Businesses externalize ecological harm, burdening public agencies.
(5) Restoration laws are limited in scope, applying only in specific circumstances.
(6) Expropriation laws are applied to economic development, rather than ecological recovery.

Addressing these legal biases requires fundamental legal and policy changes that prioritize ecological restoration over economic interests when long-term societal benefits outweigh short-term losses. The restoration hierarchy provides a conceptual and practical framework to guide this shift, ensuring that restoration efforts are aligned with ecosystem needs rather than constrained by outdated legal and economic structures.

Acknowledgment

Open access publishing facilitated by Ita-Suomen yliopisto, as part of the Wiley - FinELib agreement.

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Supporting Information

The following information may be found in the online version of this article:

Supplement S1. Electrofishing results and the social discount factor.

Guest Coordinating Editor: Volker Mauerhofer

Received: 28 February, 2025; First decision: 25 May, 2025; Revised: 19 September, 2025; Accepted: 22 September, 2025